



## A LOW- $\beta$ INSERTION DESIGN FOR 1981

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March, 1981

This report describes yet another low- $\beta$  insertion design which can be installed in the Tevatron lattice. The previous designs have been essentially of two types: one which is highly flexible in terms of tuning,  $\beta^*$ , etc., at the expense of having many different length quadrupoles, many independent power supplies, and substantial change in the regular cell structure outside of the long straight section, and a second one, invented by T. Collins, which is contained entirely within the straight section and operates on one power supply, but can only run in an off-or-on manner, and  $\beta^*$  is totally fixed. The design reported hereinafter is a modification of the second type above, which allows the insertion to be tuned to from a "normal" configuration to one with a low  $\beta^*$  adiabatically, and ultimately is able to achieve a  $\beta^*$  of around one meter. In the initial configuration, this insertion is entirely within the present straight section quadrupoles and requires no changes in the normal lattice quadrupoles and, with the replacement of the exterior quads and power supplies, can be pushed to  $\beta^*=1$  m.

Figure 1 shows four layouts of the Tevatron straight section. The top one is that of the present non-high- $\beta$  straight section (that is, all straight sections except D and A). The second line shows the type A low- $\beta$

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design which is formed by the addition of six quadrupoles within the present straight section. The main difference between this and the design of T. Collins is that here the quadrupoles are on three separate power supplies as opposed to being all in series. Tuning of this insertion entails only changing these three power supplies and no changes to the normal Tevatron except for correction elements to keep the tune constant. This is continuously changeable from all power supplies off and the normal  $\beta^*$  down to a value of  $\beta^* = 3.5$  meters. The supply #1 does go through zero, but does it in a smooth and not too critical manner and should not be a problem. All of the quadrupoles run at gradients of less than 26 KG/m. Table I lists gradients for 1 TeV for various  $\beta^*$ 's, and Figures 2-7 show the progression of the lattice functions across the straight section. The total free space for detectors available is  $\pm 21$  feet. This can be increased but at the expense of a higher ultimate  $\beta^*$ .

A modification of this design is type A', shown on line 3 of Figure 1. Type A' is made entirely of standard length quadrupoles, again run on three independent power supplies, and has almost the same properties of type A. The final low- $\beta$  is somewhat higher, 3.8 m, and the spacing between quadrupoles is less. Also, the maximum field gradient is slightly higher, although still less than 26 KG/m. Table II lists gradients for this design, and Figure 8 shows a typical beta plot.

A final, later modification is shown Figure 1 as type B. This involves replacing the short quadrupoles at stations 48 and 12 with normal cell quadrupoles and running them on separate power supplies. Thus, these quads must be ramped along with the rest of the machine and must be separately controlled. The addition of these quadrupoles, however, allows one

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to push  $\beta^*$  to 1 meter with a maximum  $\beta$  of some 850 meters. Table III shows the gradients for this case and Figure 9 is a plot of the beta functions. A few points should be noted: down to  $\beta^* \approx 5-10\text{-m}$ , the lattice functions for type B are essentially identical to types A & A'. At a value of  $\beta^* = 3-5$  meters, one family of solutions stops and another family starts. Contrary to appearances given in Table III, this does not involve Q4 power supply going to infinity, but is in fact a completely smooth and continuous transition. Finally, as shown, the gradients in Q1 get quite large. This can be relieved by having the doublet on power supply 1 consist of an 82" and a 99" quadrupole instead of two 82" quads, but this does take some distance from the free intersection region. Until more is known of the final maximum gradient of the quads, it does not seem fruitful to push the type B design too hard.

Table I (all values for 1 TeV)

$\beta^*$ (m)	60	50	40	30	20	10	5	4	3.5
Q1 (KG/m)	-52.74	29.78	112.16	199.67	299.73	432.54	546.22	591.40	660.44
Q2 (KG/m)	-635.90	-688.89	-734.50	-776.80	-841.94	-868.08	-905.54	-919.80	-941.43
Q3 (KG/m)	789.05	805.58	819.63	832.79	854.56	864.57	882.00	890.25	905.71

Type A low- $\beta$ Table II

$\beta^*$ (m)	60	50	40	30	20	10	5	4	3.8
Q1 (KG/m)	-45.54	56.08	153.44	254.10	367.23	515.54	643.75	700.44	771.59
Q2 (KG/m)	-620.74	-691.79	-750.42	-804.14	-857.13	-917.59	-963.17	-983.57	-1007.51
Q3 (KG/m)	771.66	793.39	810.62	825.94	841.10	859.50	875.96	884.21	896.46

Type A' low- $\beta$ Table III

$\beta^*$ (m)	60	50	40	30	20	10	5	3	1
Q4 (KG/m)	337.28	353.04	371.47	391.60	417.55	464.82	510.03	-51.66	-927.49
Q1 (KG/m)	82.23	109.16	141.43	188.09	250.27	337.05	464.09	1000.76	1153.65
Q2 (KG/m)	-733.90	-735.97	-740.41	-753.69	-744.76	-806.51	-872.69	-1046.57	-1086.44
Q3 (KG/m)	802.44	804.71	808.75	817.13	831.51	865.58	933.85	635.03	530.73

Type B low- $\beta$

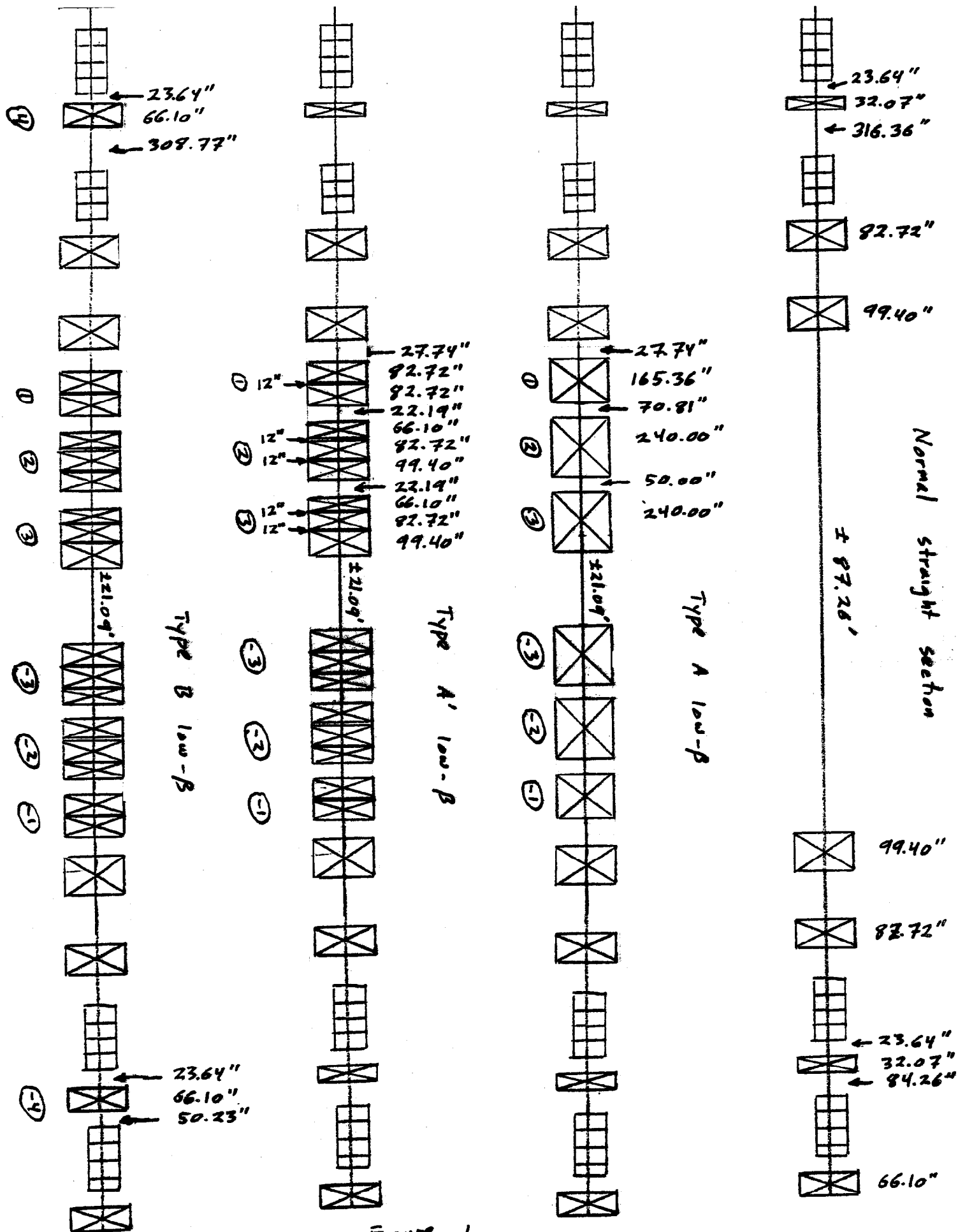
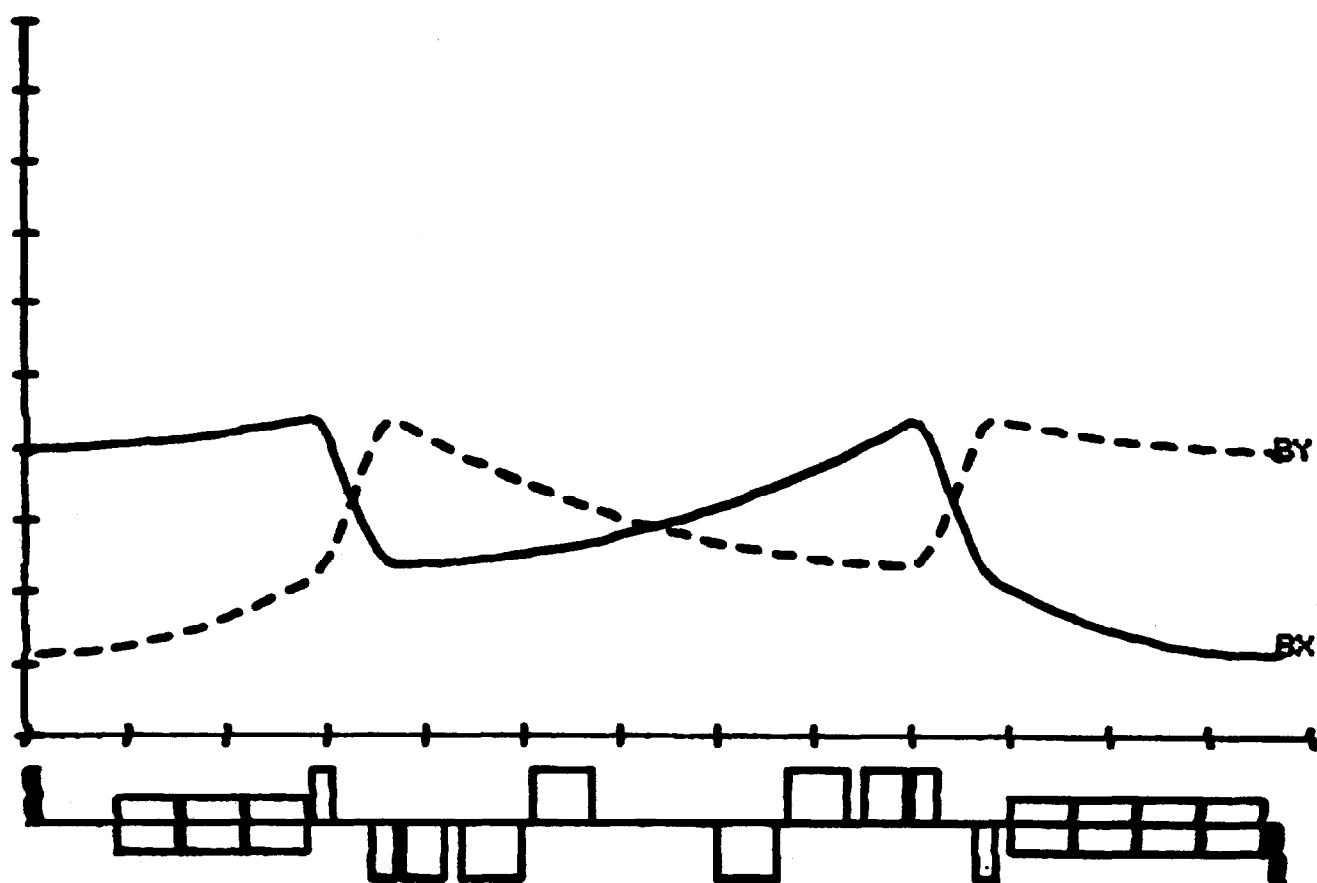


Figure 1

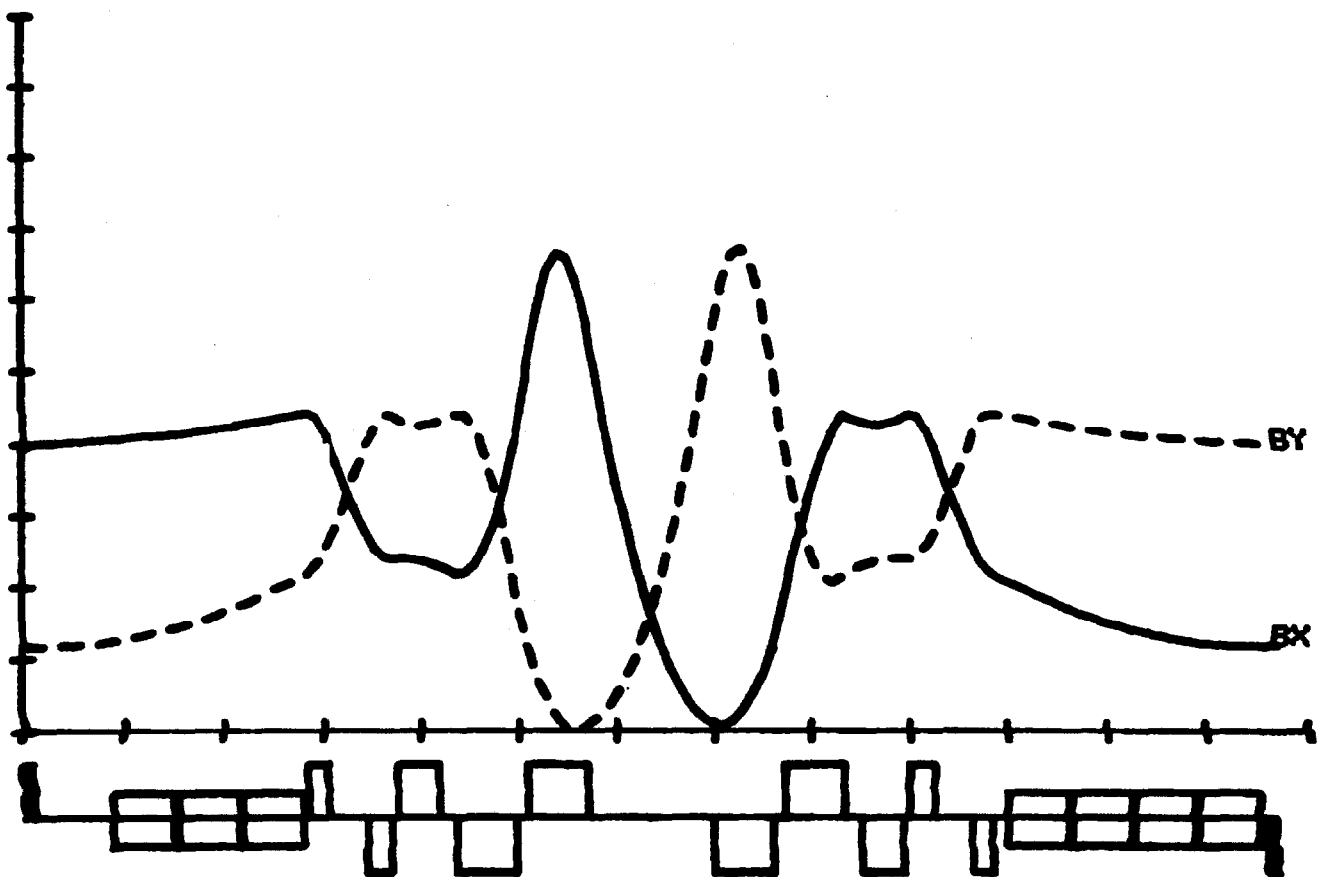
SCALES, MIN. BETA 0.00  
MAX. 250.00



Type A low- $\beta$   
inner quads off  
 $\beta^* \sim 72 \text{ m}$

Figure 2

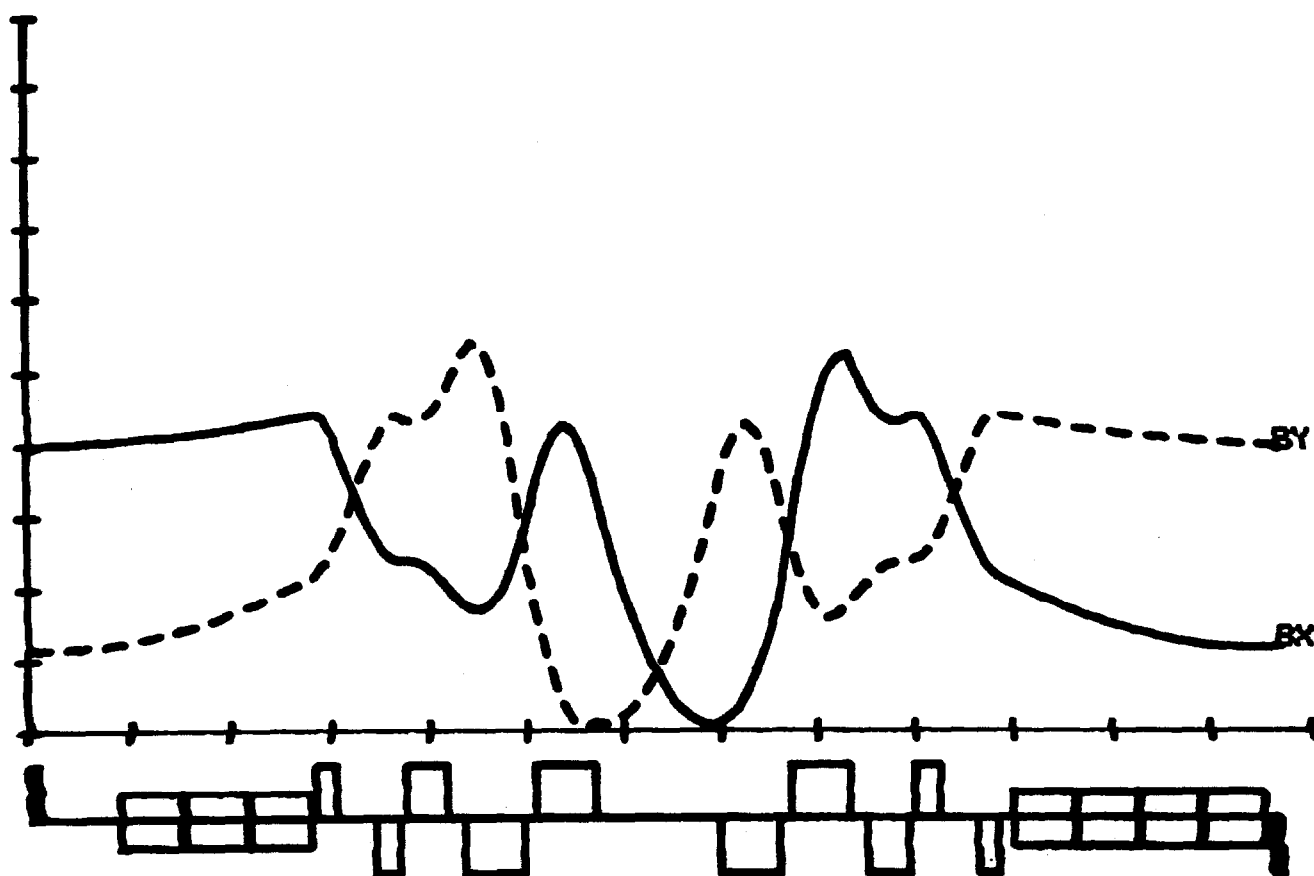
SCALES, MIN. BETA 0.00  
MAX. 250.00



Type A low- $\beta$   
 $\beta^* = 40\text{ m}$

Figure 3

SCALES, MIN. BETA 0.00  
MAX. 250.00



Type A low- $\beta$   
 $\beta^* = 20\text{ m}$

Figure 4



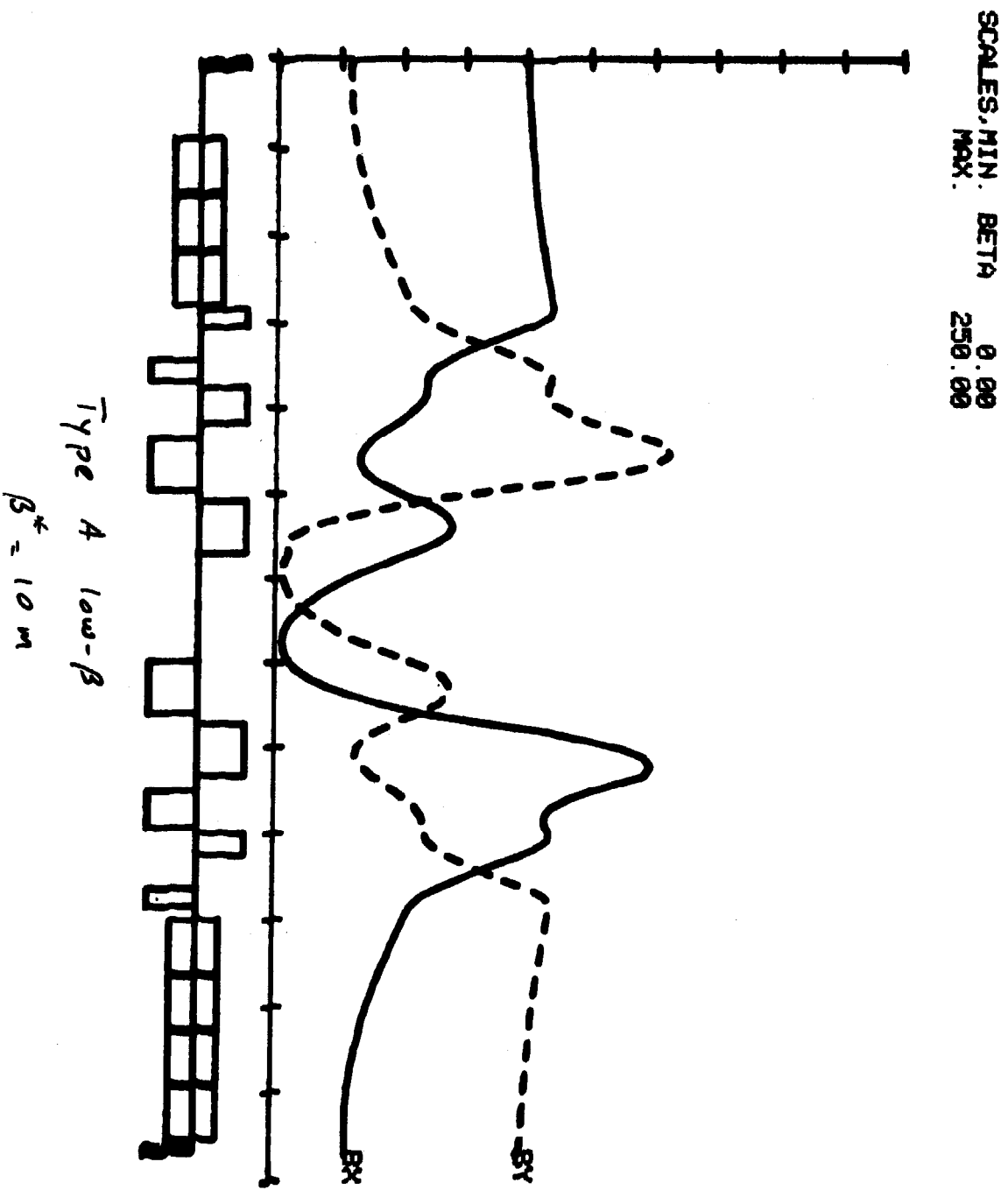
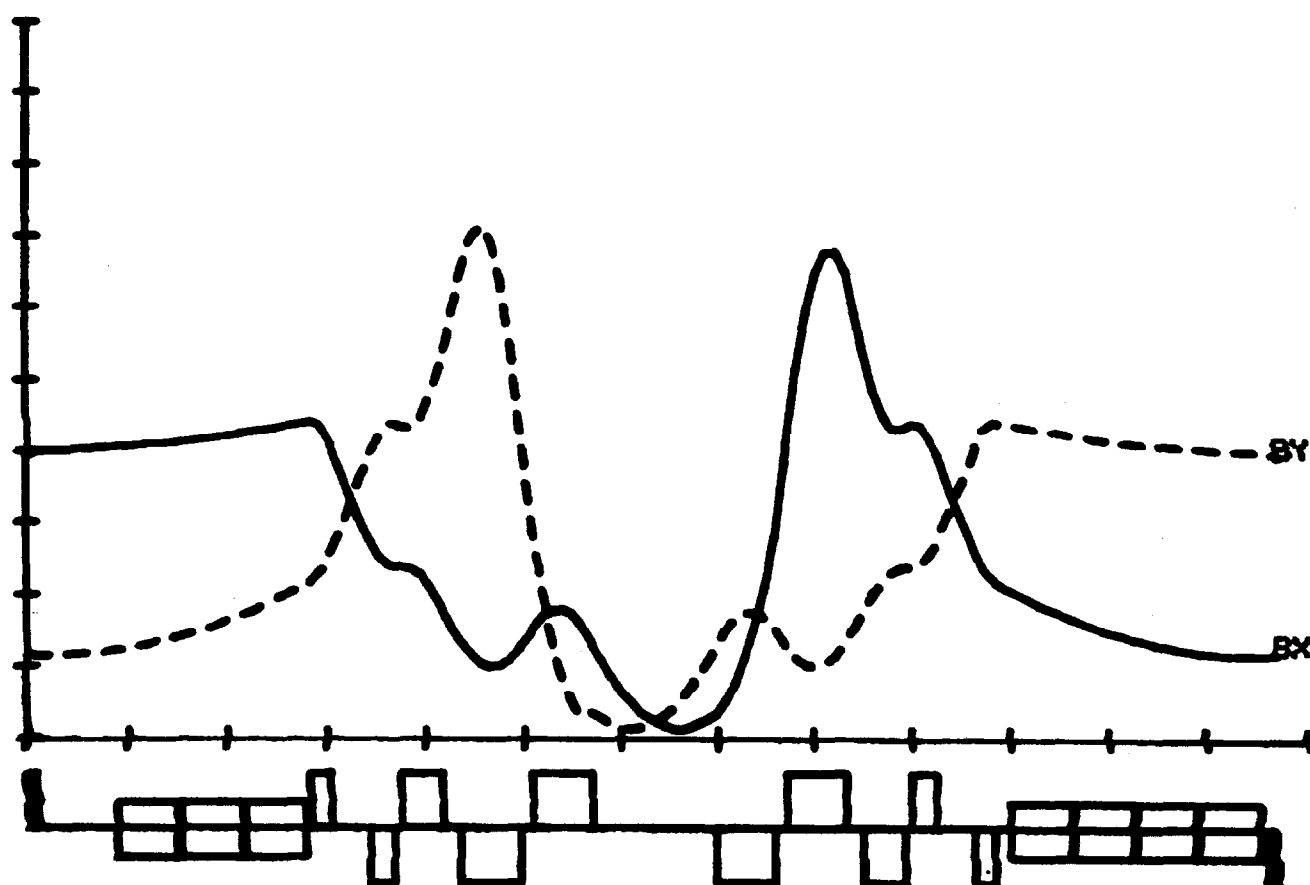


Figure 5

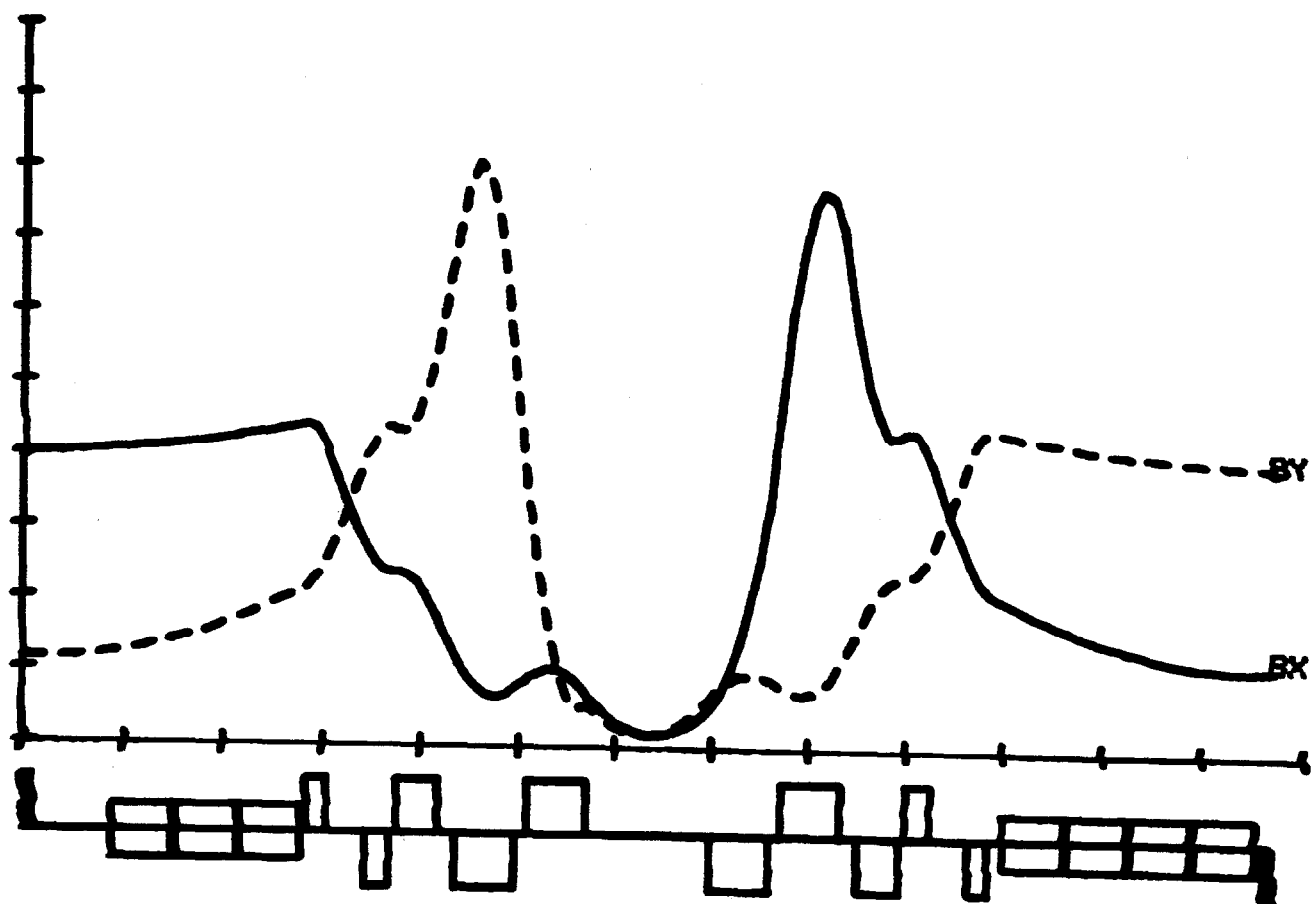
SCALES, MIN. BETA 0.00  
MAX. 250.00



Type A low- $\beta$   
 $\beta^* = 5\text{ m}$

Figure 6

SCALES, MIN. BETA 0.00  
MAX. 250.00

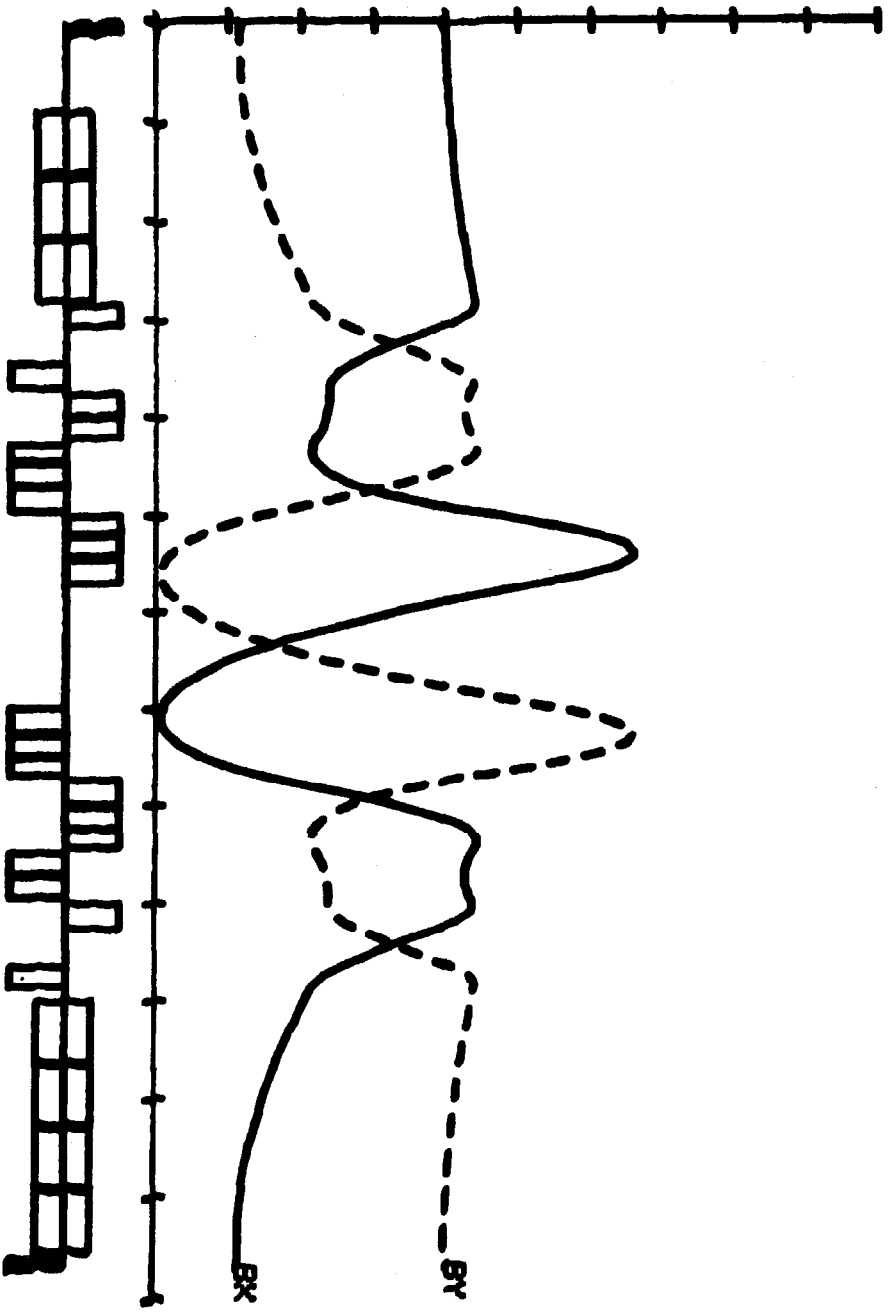


Type A low- $\beta$

$\beta^* = 3.5m$

Figure 7

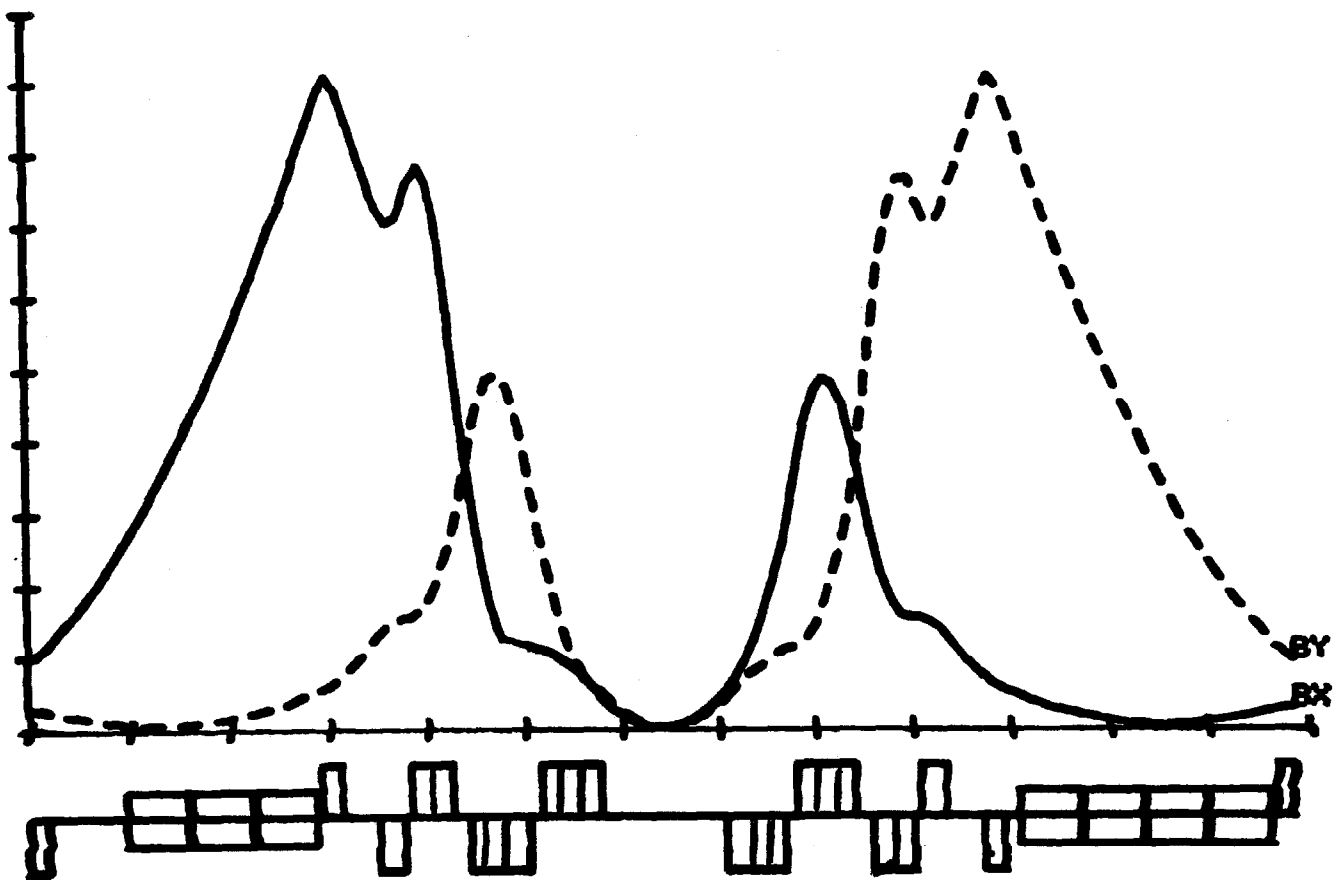
SCALES, MIN. BETA 0.00  
MAX. 250.00



Type A' low- $\beta$   
 $\beta^* = 40\text{ m}$

Figure 8

SCALES. MIN. BETA 0.00  
MAX. 1000.00



Type B low- $\beta$

$\beta^* = 1 \text{ m}$

Figure 9